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PLEISTOCENE VULCANISM OF THE COAST RANGE OF BRITISH COLUMBIA

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During the present summer the writer had occasion to visit the Mount Garibaldi region of the Coast Range of British Columbia, which lies about forty miles due north of the city of Vancouver, between 49°40′ and 50° north latitude and on the 123d meridian of west longitude. The approach to this district is by way of Howe Sound, a typical fiord, and the valley of the Cheakamous River. The volcanic origin of Mount Garibaldi, the highest peak in the region, had been recognized by members of the British Columbia Mountaineering Club, who made the first ascent of it some six or seven years ago. The region to the north of Garibaldi as far as the Black Tusk Mountain was subsequently penetrated for the first time by Mr. W. J. Gray, in whose company the present writer had the advantage of visiting the locality. The general situation, as far as it could be determined in a few days' study, is as follows:

I. PHYSIOGRAPHIC AND GLACIAL HISTORY

The Cheakamous River flows into the head of Howe Sound through a valley whose general trend is the continuation of that of the sound itself and lies in a north-northeast direction. The mountain-mass known as the Garibaldi Range lies to the eastward of it. At a point about twenty-five miles from tidewater the Cheakamous receives on the eastern side a tributary which is known as Stony Creek whose valley affords a convenient means of access to the higher parts of the range. Commencing with the bottom of the Cheakamous valley, the following features are to be observed as one ascends the range:

1. *Post-Glacial gorge*, in which the Cheakamous at present flows, cut through glacial deposits and in part through the rock to a depth of at least 300 feet.

2. *Main valley of the Cheakamous*, which has a total depth approaching 4,000 feet, and consists of well-marked inner and outer valleys. Both of these are glaciated parallel to their length. The outer valley is represented by a terrace at least a mile wide on the eastern side, and some 3,000 feet below the rim of the valley.

3. On reaching the upper edge of the valley one emerges at about 5,100 feet elevation, on a plateau, which has been dissected into broad, flat-topped spurs by the streams tributary to the Cheakamous. The surface of the plateau slopes upward to the east at an angle of from 7° to 10°, which increases toward the east, and an extension of the plateau surface probably forms the summit level of the range, at an altitude of about 8,000 feet. Incised in its surface are the remains of one or two older valleys which once ran parallel to the Cheakamous, but have since been cut across by the tributaries of that stream, and appear as notches crossing the intervening spurs. The age of this plateau is indicated by the fact that two ridges rise above it whose summits consist of remnants of andesitic lava flows, probably of early Miocene age. These flows originally probably filled valleys. The floor upon which the flow rested is now in one case, the Black Tusk Ridge, at least 1,200 feet above the plateau-surface below, while in another case, near Table Mountain, the columnar andesite itself forms a part of that surface. The end of the erosion-cycle which was responsible for the plateau can therefore hardly be earlier than Pliocene or late Miocene. On the other hand, both the plateau-surface and that of the ridges above it bear striae of the earliest glaciation of which record remains. The ice during this time covered the range up to a height of at least 6,500 feet as a sheet, whose general movement in this locality was S.S.W., or parallel to the trend of the main valleys. The plateau may therefore be assumed to be pre-Pleistocene. It is composed of rocks of Palaeozoic (probably Devono-Carboniferous)[1] age, of the subsequently intruded (Upper Jurassic) granites of the Coast batholith, and, as already explained, in some parts of the Miocene andesites. The tributary valleys which dissect it end in cirques in the upper part of the range, which are for the most part still occupied by glaciers. These valleys are of considerable depth, in one case

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[1] See O. E. LeRoy, G.S.C., *Publication No. 996*, 1908.

over 1,800 feet. Many of them are hanging valleys as regards the Cheakamous valley. They exhibit well-marked evidences of the second epoch of glaciation, which was merely an extension of the existing glaciers which filled the valley-system, including the main valleys, but did not override the range in a continuous icesheet.

II. VULCANISM

Superimposed upon the topographic featues which have been described are the andesitic cones and lava flows, which are unglaciated by the earlier icesheet, and only partially so by the later ice-advance. The volcanic foci which have been visited up to the present are three in number, but other peaks visible to the northward seem to be undoubtedly of similar origin.

Mount Garibaldi, the largest of the group and also the most southerly, is the highest peak in the region. Its summit is 8,700 feet above the sea, from which it is about 12 miles distant. It stands about 3,500 feet above the plateau. It is so surrounded by glaciers and snowfields that a study of its relations to the underlying terranes is impracticable, except possibly on the western face where freshly-cut ravines may expose sections. The walls of the cirques which have been cut into its sides afford admirable sections of the cone itself. The materials of which it is composed are of a light reddish-brown color, and appear to be largely fragmental. Lava streams extended down into the inner Cheakamous valley, where remnants of them may be seen along the Lilooet road. The proximity of the cone to the valley and the somewhat loosely coherent nature of the materials of which it is composed have rendered dissection somewhat rapid, and the conical symmetry has already been lost to a considerable extent, while the crater can only be doubtfully identified.

Situated about 5 miles to the north of Garibaldi, on the western margin of the lake of the same name, is the double volcanic cone known as Red Mountain, which has an elevation of about 1,000 feet above the plateau, or 6,500 feet above sea-level. As this volcano is much more easily accessible than Garibaldi, and practically free from snow, a fairly complete view was obtained of it. The volcanic cone stands within a cirquelike basin cut into the plateau on the south side of the valley of Garibaldi Lake. This basin consists of a wall of granite, inclosing the cone on its west and southwest sides and a summit standing out on the east side of the cone which is composed of the older Miocene andesite. This also appears to form the floor upon which the volcano stands. This basin is probably a glacial cirque. It is now almost completely filled up by the volcano, but some small areas of its floor which are exposed on the north side appear to have been almost certainly glaciated. It might otherwise have been attributed to explosive action in the early stages of the vulcanism, but there are no fragmental materials around its margin which would confirm this. The inner wall of the basin shows no evidence of glacial polishing, while the plateau above is well striated by the first glaciation. The basin seems, therefore, to have originated at a time later than the first glaciation, and is probably a cirque formed during its retreat or during the second period of ice-advance. The beginning of the volcanic activity must therefore also be dated subsequent to the first glaciation and perhaps later than the beginning of the second glaciation, if time must be allowed for the formation of the cirque. Neither of the two cones show any evidence of having been overridden by ice at any time. The older cone lies to the east. It is

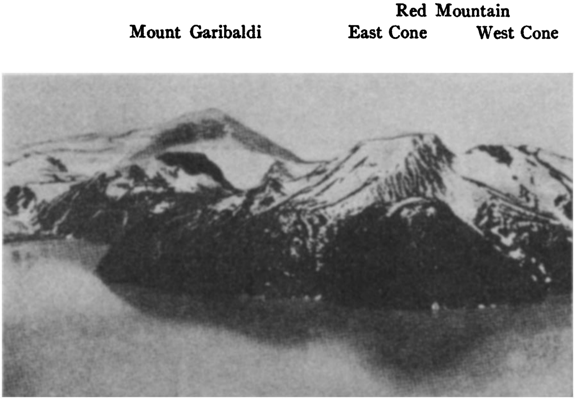

FIG. 1.—Mount Garibaldi and Red Mountain from the north. Garibaldi Lake in the foreground. The lava flow which dams it is to the right, beyond the picture. The old trunkated flow described is in the foreground. The flat-topped mountain in front of Mount Garibaldi is Table Mountain, which is composed of Miocene lavas.

more largely composed of fragmental materials than the western one, which is essentially a lava-cone. The older cone contains much material derived from the underlying rocks, especially fragments of granite and the columnar Miocene andesite which exhibit evidences of the high temperature to which they have been exposed within the vent. In the case of the granite the result is a general softening and tendency to disintegration, while the andesite blocks show cooling cracks which extend some distance from their surfaces inward.

That there was a still earlier cone which has been destroyed is proved by the remnant of a large lava-stream on the nothern side of the older remaining cone, the upper part of which has been cut off so that it presents a precipitous face, inside of which the older of the present cones has been built up. The cones as they now stand are therefore later than that from which this lava was extruded. The lower part of this old flow descended into the valley of Stony Creek, now occupied by Garibaldi Lake, but has been eroded away, probably by the glacier which occupied the valley during the second period of glaciation. This would indicate that the period of activity of this volcano extended back into the later of the two glacial epochs.

There is, on the other hand, abundant evidence that vulcanism continued for some time after the ice had retreated nearly to its present limits. Lava-flows from the western crater of Red Mountain have filled Stony Creek valley for a distance of about a mile and a half, and their surfaces are entirely unglaciated. The resultant damming of the creek has produced Garibaldi Lake, whose waters now find their outlet along a channel between the edge of the lava-flow and the northern wall of the valley until they reach a recess in the lava which forms the basin of Lesser Garibaldi Lake. From this point onward the stream follows a subterranean channel under the lava flow, beneath which it reappears at the foot of the cliff known as "the Barrier," which has been formed by the undercutting of the lower end of the lava-flow. At times of exceptionally high water, a part of the stream flows over the surface to Stony Lake, and thence over the Barrier into the lower valley. The cutting away of the lava here has exposed a section of the flow, which can be seen to rest upon glacial till, and upon rock surfaces which bear striae belonging to both periods of glaciation. These later lava-streams are therefore undoubtedly post-glacial. Their surface is covered with a well-grown forest.

A small cinder-cone, some 500 feet in height, about four miles north-northeast of Red Mountain, is the most northerly volcanic vent examined. It stands in the mouth of a large cirque which faces the north and opens upon a valley known as Desolation Valley. This is an abandoned glacial hanging valley and contains a number of lakes. Its floor is about 5,350 feet above sea-level. The cirque contains a large snow-field, whose lower edge rests against the side of the volcanic cone and discharges by a glacier on each side of it. There is evidence that the ice at one time overrode parts of the cone which are now free from it, and probably filled the valley on the north side of it since the volcano was active. A small lake lying in the valley is rapidly being filled by a delta of outwash from the glacier, most of which consists of volcanic materials. A glacial stream which flowed over the western part of the cone from the snow-field behind it has cut a ravine in the flank of the cone in which a cross-section of the faulted tufaceous strata is well shown. The summit is 5,850 feet above sea-level and the cone has a crater about 70 feet deep, which was partially filled with water at the time of our visit.

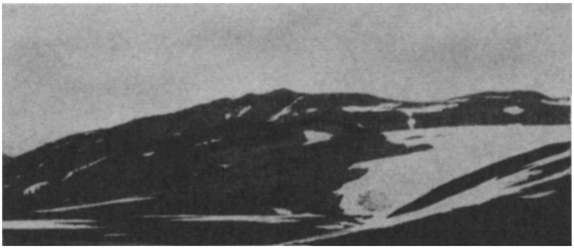

FIG. 2.—Cinder Cone in Desolation Valley. The cone is in the middle distance covered with dark bushes. To the right is a snow-field, and one of the glaciers discharging from it beside the cone. In the left foreground are a small lake and the outwash-delta of the glacial stream. The ridge which bounds the snow-field forms the background.

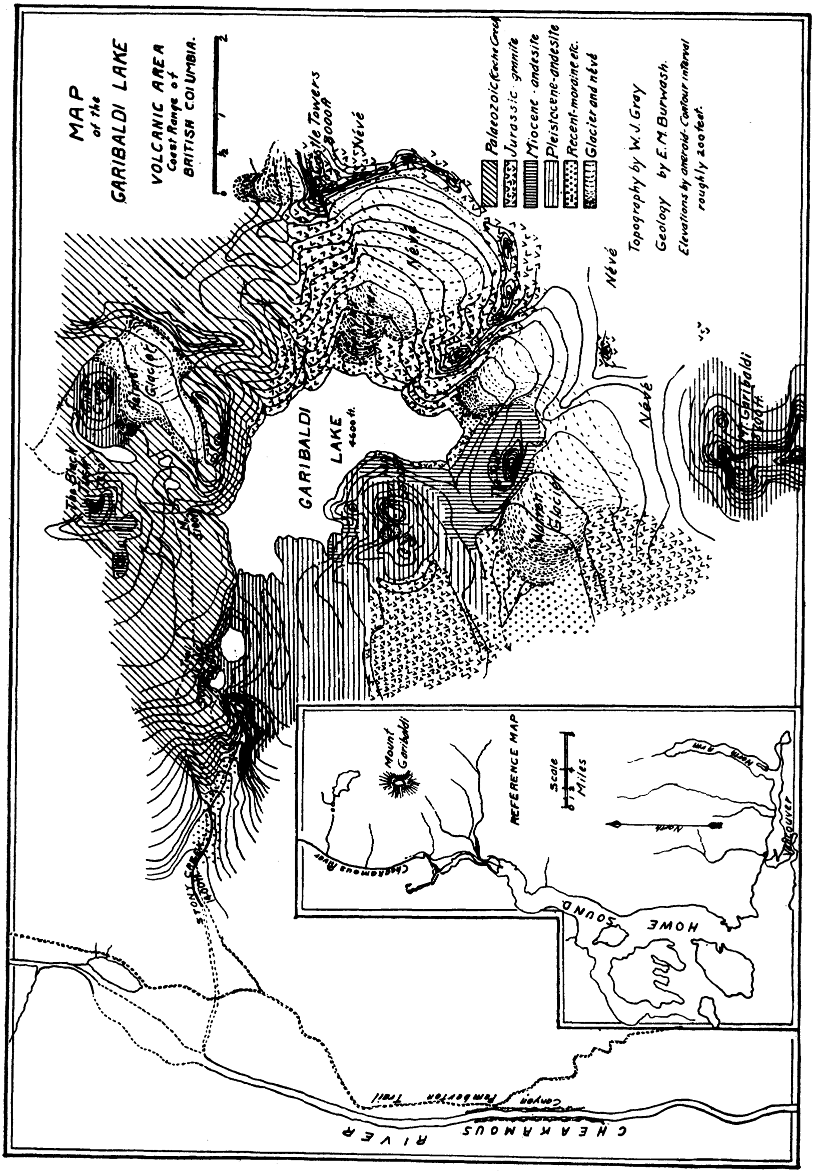
MAP of the GARIBALDI LAKE
VOLCANIC AREA Coast Range of BRITISH COLUMBIA
Palaeozoic
Jurassic granite
Miocene-andesite
Pleistocene-andesite
Recent-moraine etc.
Glacier and névé
Topography by W. J. Gray
Geology by E. M. Burwash
Elevations by aneroid - Contour interval roughly 200 feet.
Castle Towers 8000 ft
Névé
GARIBALDI LAKE 4600 ft.
Mt. Garibaldi
Glacier
Warren Glacier
The Black Tusk
Stony Creek
REFERENCE MAP
Mount Garibaldi
Scale Miles
North
Cheakamus River
HOWE SOUND
Vancouver
Canyon
Pemberton Trail
CHEAKAMUS RIVER

FIG. 3

The age of this cone appears to correspond with that of Red Mountain. Neither can be said to have originated as far back as the first glacial period. In the tills, however, which represent the end of that period in the Capilano Valley, near Vancouver, there are blocks of the reddish andesitic lava which is characteristic of this period of vulcanism. This locality lies south of Mount Garibaldi, and could only be reached by ice of a general glaciation, moving over the summits of the higher ridges. It is probable, therefore, that Mount Garibaldi is of considerably earlier date than either of the smaller vents to the northward, and that the lava erratics of the Capilano Valley may be referred to the early eruptions of Mount Garibaldi. This would also agree with the extensively dissected condition of the Garibaldi cone as compared with the others. The total time-range of the vulcanism would therefore extend from early Pleistocene through a considerable part of the Recent, if we suppose the earliest recorded glaciation to have been in fact the earliest of the Pleistocene ice-ages. In any event, we must place the beginning of the vulcanism well back in the Pleistocene.

The nature of the lavas, which are reddish-brown andesites and andesite-porphyries indicates a lithological relationship with the Pleistocene volcanics of the Pacific coast states. The zone of activity is thus extended from Mount Baker in a north-northwest direction for about 100 miles, and into a quite new geological province, that of the Coast Range batholith.